9 Multilevel Analyses and Reductionism: Why Social Psychologists Should Care about Neuroscience and Vice Versa

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Social and biological explanations of behavior have often been considered to offer distinct, or even incompatible, alternative accounts. This was not always the case, however. The Darwinian revolution attracted broad attention and generated infectious enthusiasm for understanding the biological bases of social behavior (for review, see Berntson & Cacioppo, 2000b). Unfortunately, attention faded and enthusiasm soon dampened, due in large part to the vacuous application of simplistic and untestable biological causes (e.g., instincts) to explain all social behavior. By the middle of the twentieth century, a deep schism and enduring mutual suspicion had arisen between social psychologists and psychobiologists; their respective professional "evolutions" began to diverge.

Psychobiologists emphasized physiological processes, neural substrates, and production mechanisms for behavior, often eschewing mentalist and functionalist theories, or considering them subject to reductionism. In contrast, social psychologists emphasized multivariate systems, situational influences, and practical applications, and strongly rejected reductionism. Consequently, these psychological subdisciplines progressed along two diverging trajectories that yielded what some regarded as an unbridgeable rift between social and biological approaches (Scott, 1991). Minimally, these divergences resulted in vastly different subject samples, research traditions, methodologies, and theoretical perspectives.

As unbridgeable as this rift may have seemed at one time, several major developments are helping to allay the once profound mutual suspicion between social psychology and psychobiology. One is the increasing recognition that psychobiological perspectives can offer important insights into complex social problems, such as aggression or drug addition, and that social processes are not only consequences of, but also impact on, psychobiological operations. In addition, recent methodological developments, such as functional brain imaging, now offer a powerful research armamentarium that supports meaningful studies of brain systems and social processes. Finally, the utility of interdisciplinary, multilevel approaches and analyses in understanding complex systems has contributed to the emergence of social neuroscience. This discipline is grounded in the recognition of the inherent links across levels of organization and analysis and in the fundamental construct of reductionism, as opposed to substitutionism. *Reductionism* embraces the ability to relate one level of organization (e.g., the social) to another (e.g., the hormonal), but recognizes that causal links between levels go both ways, and that lower levels of analysis can never entirely replace or substitute for higher-level analyses. The opposing construct of *substitutionism* holds that one level of analysis (generally a higher) can be replaced or supplanted by another level (generally a lower), and the goal of science is the pursuit of explanations at the lowest possible level of analysis. In contrast to this view, and in agreement with reductionism as defined here, emerging perspectives in neuroscience, and especially the new field of social neuroscience, emphasize the complementing nature of social and biological levels of analysis and how each can contribute to an understanding of complex behaviors and the mind.

Social Neuroscience

We are pleased to have contributed to the emergence of the field of social neuroscience (Cacioppo & Berntson, 1992; Cacioppo et al., 2002; Ochsner & Lieberman, 2001). Although there has been a rich history of research linking social and biological perspectives, it has been only recently that the field has developed a coherent presence and a clear identity. Indeed, not until 1992 was the term *social neuroscience* introduced as a descriptive label for this field (Cacioppo & Berntson, 1992).

Before starting our collaborative program in 1989, we had both established programs entailing multiple levels of analysis, which extended from the social to the psychophysiological level (Cacioppo); and from the psychophysiological to the neural level (Berntson). We shared a recognition of the importance of cross-level analyses, and the merging of our research and perspectives afforded the groundwork for a collaborative effort extending from the macro (social) to the micro (neural) levels of organization and analysis. Two early findings from our collaborative effort illustrate the utility of multilevel analyses. One deals with the impact of social factors on autonomic cardiovascular control and health, and the other on the potential impact of autonomic states on higher social and cognitive processes.

Multiple Levels of Organization: Top-Down Influences of Social Factors

The autonomic nervous system has traditionally been viewed as a homeostatic mechanism for maintaining a stable internal state. This perspective emerged from early research in the Walter Cannon era that focused on the peripheral components of the autonomic nervous system and the homeostatic reflex mechanisms of the lower brain stem that regulate these peripheral pathways. It is now clear that higher neural systems also impact autonomic control, and often in a fashion that does not comport with a simple homeostatic model, but rather reflects an *allodynamic* process through which more flexible and adaptable patterns of control can be achieved (see Berntson, Cacioppo, & Quigley, 1991; Berntson & Cacioppo, 2000a). An illustration of this comes from studies of autonomic responses to stressors.

In accord with the homeostatic reflex model of autonomic control, the sympathetic and parasympathetic nervous systems, which often have opposing effects, have been traditionally viewed as reciprocally controlled. When one branch is activated, the other is inhibited, and thus both branches act synergistically to achieve the same outcome. An increase in blood pressure, for example, results in a reflexive activation of parasympathetic outflow and a parallel reduction in sympathetic outflow. The increased parasympathetic activity results in a slowing of the heart, and the decreased sympathetic activity yields a further reduction in heart rate as well as a relaxation of vascular walls and consequent vasodilation, all of which oppose the blood pressure perturbation. The brainstem neural circuitry and neurophysiological mechanisms that underlie

this reflexive hemostatic control have been fairly well characterized.

Findings from our studies of stressors confirm this reciprocal mode of autonomic control with changes in blood pressure. We employed single and dual pharmacological blockades of the autonomic branches to examine sympathetic and parasympathetic responses to the physiologic stress of standing up from a sitting position (orthostatic stress), which reduces blood pressure and triggers a homeostatic reflex response. Results revealed an increase in heart rate attributable to an increase in sympathetic control, together with a decrease in parasympathetic control. In accord with the reciprocal model of control, the individual responses of the two branches of the autonomic nervous system were highly (negatively) correlated. There is ample support for the historical focus on the reciprocal mode of autonomic control, but this model is incomplete. Although it may apply to many lower reflexes, higher neurobehavioral systems (e.g., those mediating social cognition) can have more diverse influences on autonomic control.

In the same blockade study, we also determined autonomic responses to social-cognitive stressors (e.g., speech stress). At a group level, the social stressor also yielded an increase in heart rate, comparable to the orthostatic stressor, which was associated with an overall sympathetic activation and parasympathetic withdrawal. In contrast to the orthostatic stressor, however, there were considerable individual differences in the pattern of response, and hence there was no correlation between the activities of the autonomic branches. Rather, some subjects showed a rather selective and reliable increase in sympathetic control, others a selective decrease in parasympathetic control, and still others showed various combinations of these responses.

These and similar findings, in a social context, have mandated an expansion of a major physiological model of autonomic control.

Autonomic states can no longer be viewed as lying along a single continuum from sympathetic to parasympathetic dominance, but rather can assume a broader range of functional states described by an autonomic space. This autonomic space is described by a bivariate representation, in which sympathetic activity is indicated along one axis and parasympathetic activity along an orthogonal axis. This autonomic space model can thus incorporate all possible combinations of sympathetic and parasympathetic activities, as well as response patterns characterized by independent, reciprocal, or even coactive changes in the two autonomic branches (Berntson & Cacioppo, 2000a). These are important findings because individual patterns of response may reflect distinct psychological states and have differential implications for health. These considerations point to the need for more sophisticated conceptualizations of stress.

Although orthostatic stress yielded highly concordant responses in all subjects, there were individual differences in the pattern of autonomic response to psychological stress, and these differences (but not the former) were predictive of neuroendocrine and immunological status. Specifically, sympathetic cardiac reactivity, but not parasympathetic cardiac reactivity or overall heart rate change, was predictive of hypothalamic pituitary-adrenocortical response and (inversely) of the immunological response to vaccine (Cacioppo, 1994; Cacioppo et al., 1995). Similarly, the clinical outcome after myocardial infarction appears to be a function in part of the specific pattern of cardiac autonomic control, with sympathetic control being a

risk factor and parasympathetic control having a protective effect.

The impact of social factors on autonomic and neuroendocrine control has also become apparent through our recent research on loneliness. Personal ties are a ubiquitous part of life, serving important social, psychological, and behavioral functions across the life span. Moreover, it is becoming increasingly apparent that positive social relationships are important for physical and psychological well-being.

Epidemiological research has found that social isolation is a major risk factor for morbidity and mortality from widely varying causes, including cardiovascular diseases, even after statistically controlling for other known risk factors. Moreover, experimental research in animals has further confirmed that social stressors can contribute to cardiovascular disease in primates. Although there are several routes by which social factors may impact health, one likely candidate is a unique pattern of autonomic and neuroendocrine control that appears to characterize loneliness (Cacioppo et al., 2002).

Importantly, in the absence of measures and analyses at the social or macro level, the effects of loneliness on health would be obscure, and individual differences attributable to these factors would simply appear as error variance in medical models.

Multiple Levels of Organization: Bottom-Up Influences

The social neuroscience perspective entails not only considerations of how social factors impact biology, but also how social processes are realized in the brain, and how biological factors may impact these mechanisms. There is now an expanding literature on brain systems that mediate social processes, ranging from neurophysiological and neurochemical studies in animals to brain-imaging studies in humans. Our focus in this area, however, has been decidedly more cross-level. That is, we have asked how lower-level factors, such as autonomic states, might impact higher-level cognitive and social processes (Cacioppo, Berntson, & Klein, 1992; Berntson, Sarter, & Cacioppo, 2003). This has been a topic of interest since William James articulated what is now referred to as "the James-Lange theory of emotion," in which emotions are considered to be the perceptual consequences of somatovisceral feedback.

Although the strong form of this concept is no longer tenable, it is increasingly clear that bottom-up, ascending visceral influences can importantly modulate higher-level processes such as memory, emotion, and cognition (Cacioppo et al., 1992; Berntson et al., 2003). Indeed, the specific neural pathways mediating these effects are beginning to be elucidated. Parallel noradrenergic and cholinergic routes extend from visceral sensory receiving areas in the nucleus of the tractus solitarius, directly and indirectly to the locus coeruleus, the amygdala, the basal forebrain cholinergic system, and the cerebral cortex. These ascending systems have been repreatedly implicated in neurobehavioral processes. Damasio and colleagues (see Damasio, 1994), for example, offer neuropsychological evidence that the amygdalocortical (especially medial prefrontal) circuits are involved in guiding behavior based on environmental and somatovisceral feedback. Additionally, the ascending basal forebrain cholinergic system is an important regulator of cerebral cortical function and has been implicated in cortical activation, attention, anxiety, and cognition (Berntson, Sarter, & Cacioppo, 1998, in press). These ascending regulators of cortical state

strongly impact the highest-level cortical processes that underlie the unique characterstics, accomplishments, and sociocultural heritage of the human race.

The concept of an ascending regulatory system in the brain has been with us since the work in the mid-twentieth century on the ascending reticular activating system and arousal. The arousal construct promised to link cognitive function with neural mechanisms and had broad impact on psychology and social psychology. This construct died a merciful death, as it became apparent from the behavioral perspective that arousal is neither monolithic nor continuous. It also became apparent from the neuroscientific perspective that what was thought to be a rather homogenous and nonspecific ascending arousal system in fact comprises multiple, neurochemically and neuroanatomically differentiated and functionally specific pathways. This is a particularly exciting set of developments; work in this area is beginning to clarify conceptual complexities and empirical inconsistencies in the "arousal" literature and to more critically elucidate brain-behavior relations. It also illustrates how behavioral and neural analyses can yield converging insights and constrain or inform concepts and theories across levels of analysis.

Summary

There is much to be gained by multilevel analyses in general, and social neuroscience approaches in particular. A rational reductionistic approach, one that eschews substitutionism, can benefit each level of analysis. All behavior is biological, but biological reductionism does not yield a simple, singular, or satisfactory explanation for complex behaviors, and micro forms of representation do not provide the only or even necessarily the best level of analysis for understanding human behavior. Micro or neural perspectives and analyses may offer tremendous insights on macro or social processes. On the other hand, macro constructs of the social sciences provide an efficient means of organizing and understanding highly complex activity without needing to specify each individual action of the simplest components (Cacioppo, Berntson, Sheridan, & McClintock, 2000). Moreover, macro constructs serve to define issues and topics that serve as the subject matter for micro approaches and often represent the dependent variables that allow evaluation of theories and inferences derived from micro approaches. It is the mutual interaction, calibration, and orchestration across levels of analysis that will represent the next important wave of developments in the social sciences.

Although descending and ascending neural influences generally act synergistically, there are discernible effects and interactions from processes at distinct levels of the neuraxis. Primitive protective responses to aversive stimuli, for example, are organized at the level of the spinal cord, as is apparent in flexor (pain) withdrawal reflexes that can be seen even after spinal transaction (Berntson, Boysen, & Cacioppo, 1993). These primitive protective reactions are expanded and embellished at higher levels of the nervous system. The evolutionary development of higher neural systems, such as the limbic system, endowed organisms with an expanded behavioral repertoire, including escape reactions, aggressive responses, and even the ability to anticipate and avoid aversive encounters (Berntson et al., 1993). Evolution not only endowed us with primitive, lower-level adaptive reactions, but it sculpted the remarkable information processing capacities of the highest levels of the brain. Thus neurobehavioral mechanisms are not localized to a single level of organization within the brain, but rather are represented at multiple levels of the nervous system. At progressively higher (more rostral) levels of organization (spinal, brain stem, limbic, cortical regions) there is a general expansion in the range and relational complexity of contextual controls and in the breadth and flexibility of discriminative and adaptive responses (Berntson et al., 1993).

Adaptive flexibility of higher-level systems has costs, given the finite information-processing capacity of neural circuits (Berntson et al., 1993). Greater flexibility implies a less rigid relationship between inputs and outputs, a greater range of information that must be processed, and a slower serial-like mode of processing. Consequently, the evolutionary layering of higher processing levels onto lower substrates has adaptive advantage in that lower and more efficient processing levels may continue to be utilized and may be sufficient in some circumstances (Berntson et al., 1998). Higher neurobehavioral processes, however, can come to suppress or bypass pain withdrawal reflexes (Boysen, Berntson, Hannan, & Cacioppo, 1996). A person unwittingly touching a hot flame normally experiences a rapid, autonomic, reflexive withdrawal from the painful fire. If, however, the person hears a child on the other side of a wall of flames, this defensive reflex can be overridden by higher-level motivations, with the person most likely looking for a doorway or passage not engulfed by flames or donning fire-retardant covering (e.g., a wet blanket) before challenging the fire to retrieve the child. Both animal models and a variety of noninvasive recordings in humans (event-related brain potentials, functional magnetic resonance imaging) have proved useful in exploring the more complex interactive processes across levels of the neuraxis, and new methods and approaches are continually emerging. This is an especially exciting effort—multilevel approaches will be central in understanding the brain and behavior.

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